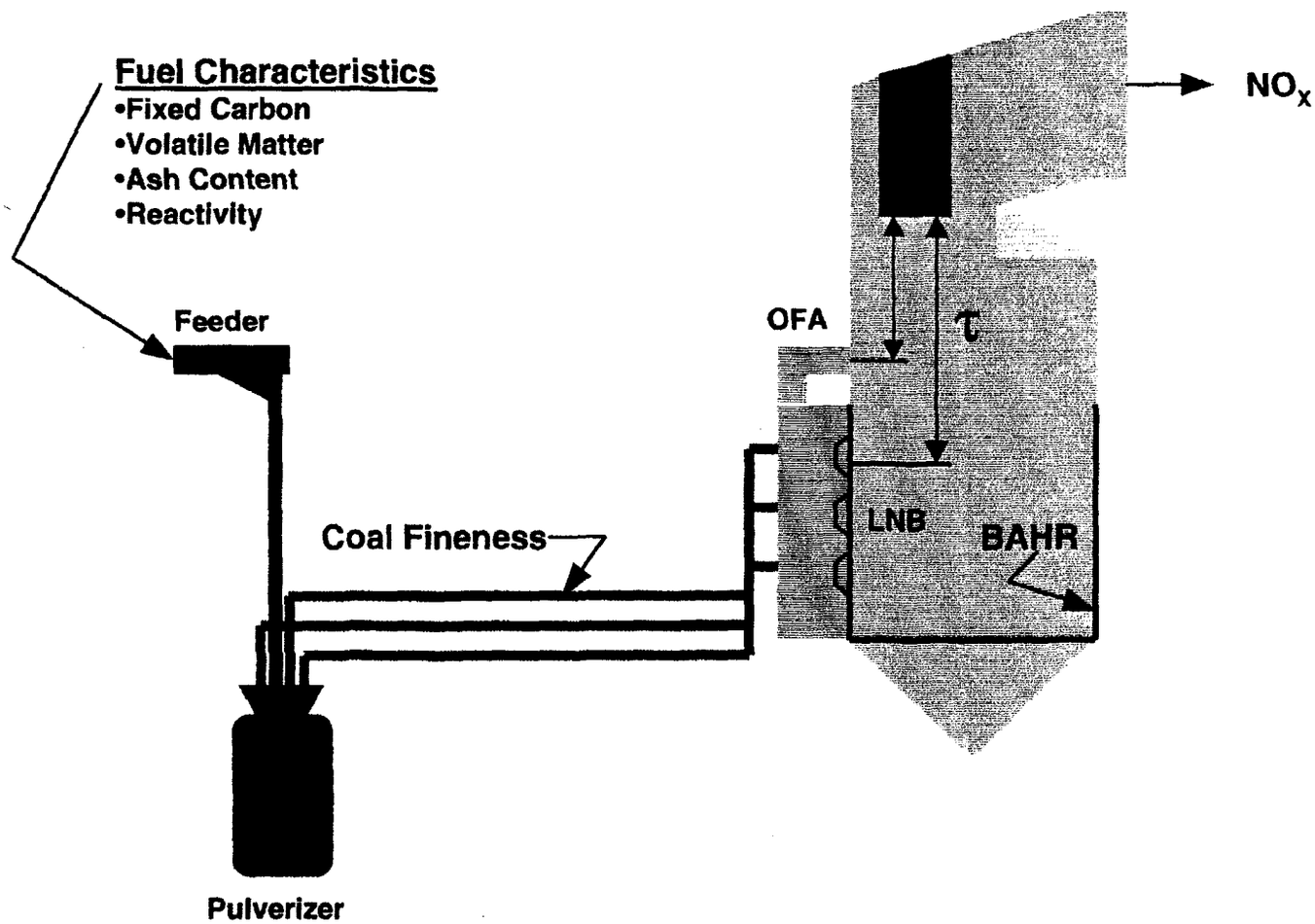
OFA SYSTEM DESIGN OVERVIEW

OFA System Design Experience

- conducted major OFA design study for EPRI in mid-1980's (2154-6)
  - 1/12 scale 3D physical flow modeling
  - determined key OFA system design design parameters
    - location (furnace residence time)
    - uniform distribution
    - penetration (adequate pressure and velocity)
    - mixing
    - turndown (1/3, 2/3 area flow control dampers)
    - biasing capability
- installed OFA base (coal fired)
  - greater than 5,400 MW (1990 to present)
  - 33 units (BBPI, B&W & FW)

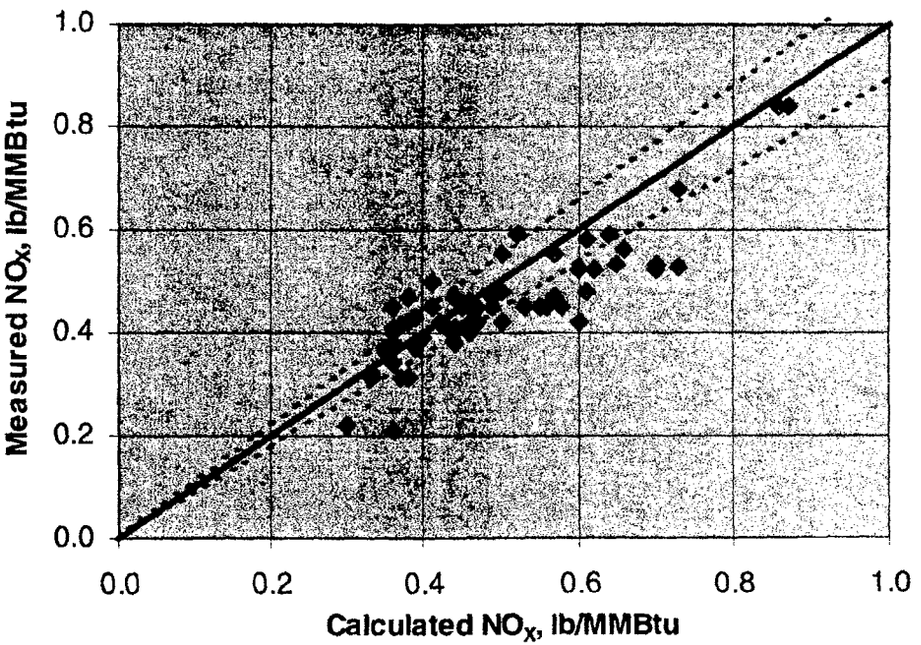
NOx & UBC Factors



NO_X Emission Correlation Parameters

$NO_X = f$ (BAHR, SR_B, XSA, FC, VM, N, SA)

BAHR = Basket Area Heat Release
SR_B = Burner Zone Stoichiometry
XSA = Excess Air
VM = Volatile Matter Content
FC = Fixed Carbon Content
SA = Coal Spreader Angle
N = Nitrogen Content



NOx / UBC Correlation Inputs

- BAHR = 304 kBtu/hr/ft^2
- residence time OFA to furnace exit = 1.5 s
- excess air = 13.5% & 18%
- SR_B = 1.0 & 0.95
- fuel characteristics:
  - FC=46.97%, VM=38.74%, M=5.02%, A=9.27%
  - FC/VM=1.21
  - S=0.50%
  - HHV=12,268 Btu/lb
- fineness: 99% passing 50 mesh, 70% passing 200 mesh

Predicted vs. Guaranteed Performance

	prediction	guarantee
NOx (lb/MMBtu)	----	0.37
SR_B=1.0, XSA=13.5%	0.33	----
SR_B=0.95, XSA=18%	0.31	----
CO (ppm)	90	100
flyash UBC (%)	----	4.25
SR_B=1.0, XSA=13.5%	< 3.8	----
SR_B=0.95, XSA=18%	< 3.7	----

OFA System Design Details

- OFA port dimensions: 36 in. H x 23.5 in. W
- distance upper burners to OFA: 15 ft (1 burner elevation)
- case I: $SR_B = 0.95$ (19% OFA), XS air = 18%
- case II: $SR_B = 1.0$ (12% OFA), XS air = 13.5%

	ideal	case I	case II
residence time burners to OFA	0.4	0.47	0.49
residence time OFA to furnace exit	1.0	1.54	1.48
furnace velocity, V_F (fps)	----	32	31
OFA nozzle velocity, V_O (fps)	----	165	97
V_O/V_F	4.5 / 3.0	5.4	3.0
port aspect ratio (H/W)	1.5	1.53	1.53
ΔP feeder duct inlet to port outlet (iwc)	----	4.8	1.8

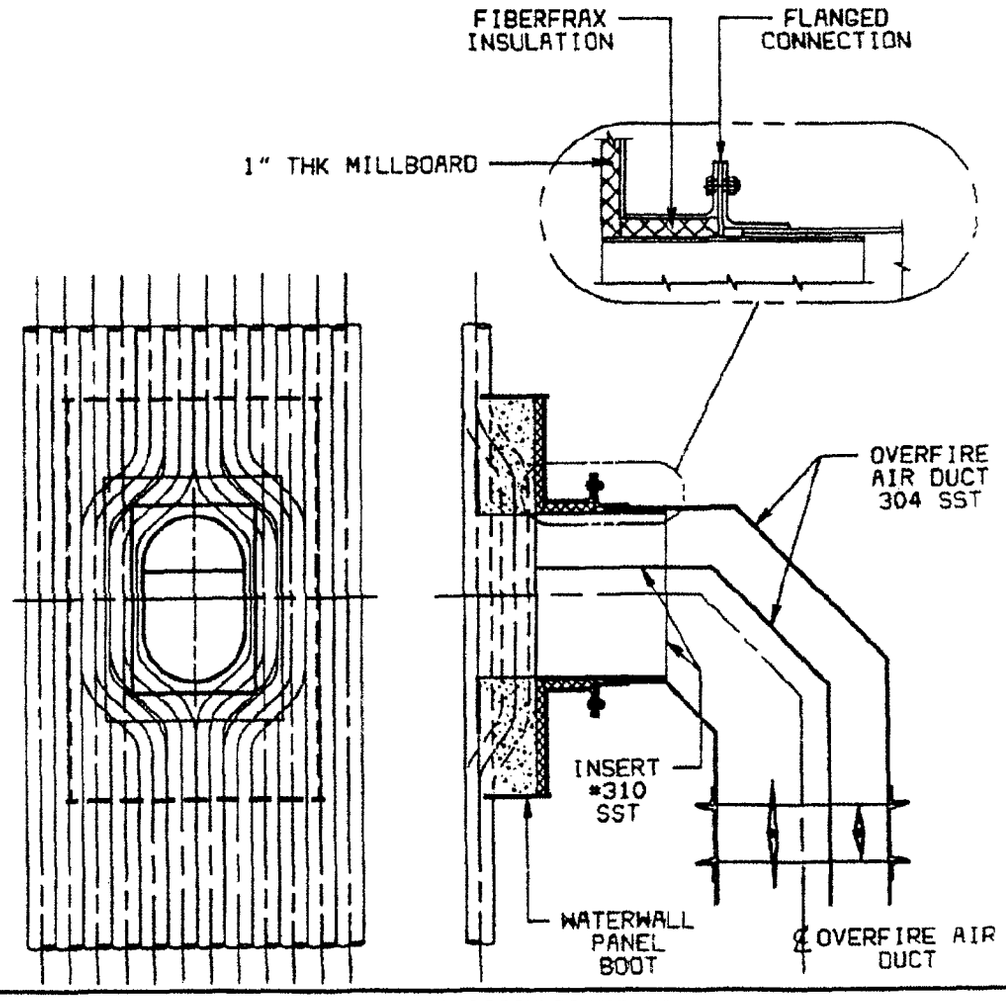
OFA System Major Components

- (16) ports (12 over-burner + 4 wing) each with:
  - bent tube opening & seal box
  - elbow duct with 1/3-2/3 damper assembly
  - (1) AMC 1SS OFA flow probe for balancing port to port
- new OFA windbox compartment
- (4) feeder ducts each with:
  - (1) fabric expansion joint
  - (1) flow control damper
  - (1) AMC 1SS flow probe for balancing
  - (1) flow transmitter
- (4) Jordan 5_00 electric rotary actuators and interconnecting linkages each operating (4) 1/3 dampers
- (4) Jordan 5_00 electric rotary actuators and interconnecting linkages each operating (4) 2/3 dampers

Typical OFA Damper Control Philosophy

boiler load (%MCR)	1/3 damper	2/3 damper
below 60%	closed	closed
60-75%	open	closed
75-90%	closed	open
90-100%	open	open

Standard OFA Nozzle Mechanical Design

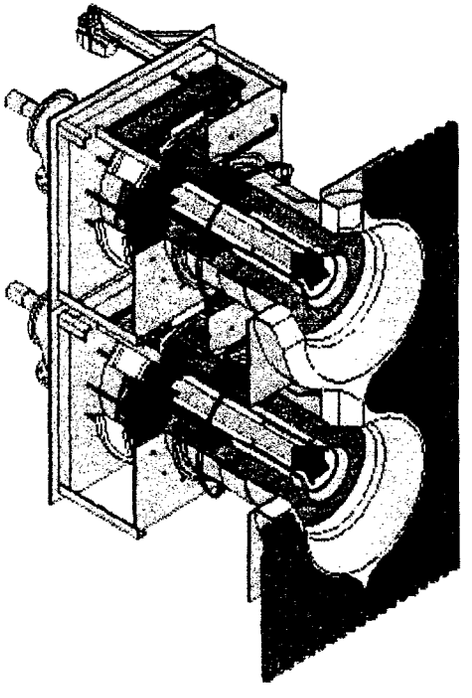


Jordan SM-5120 Rotary Actuator

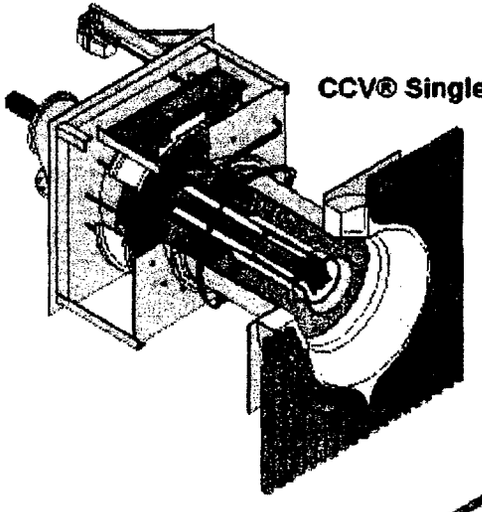
- Input voltage: 120V / 1Ph / 60 Hz
- Motor rating: continuous modulation
- Position feedback signal: 4 mA open / 20 mA closed
- Over-torque protection
- Torque switches: open & closed
- "Power on" relay
- Enclosure rating: NEMA 4
- Hand wheel for manual override capability

OPTIONS FOR UNIT 1

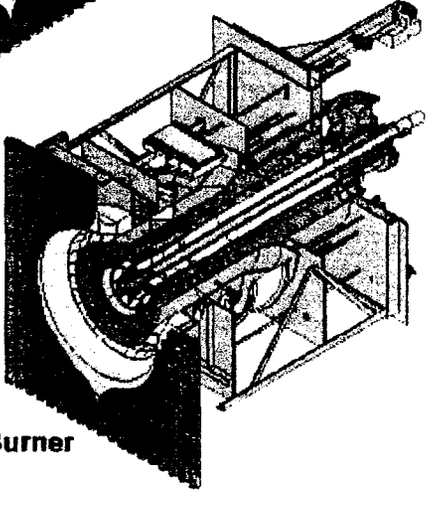
Babcock Borsig Power, Inc.
Low-NOx CCV® Burners



CCV® Cell Burner

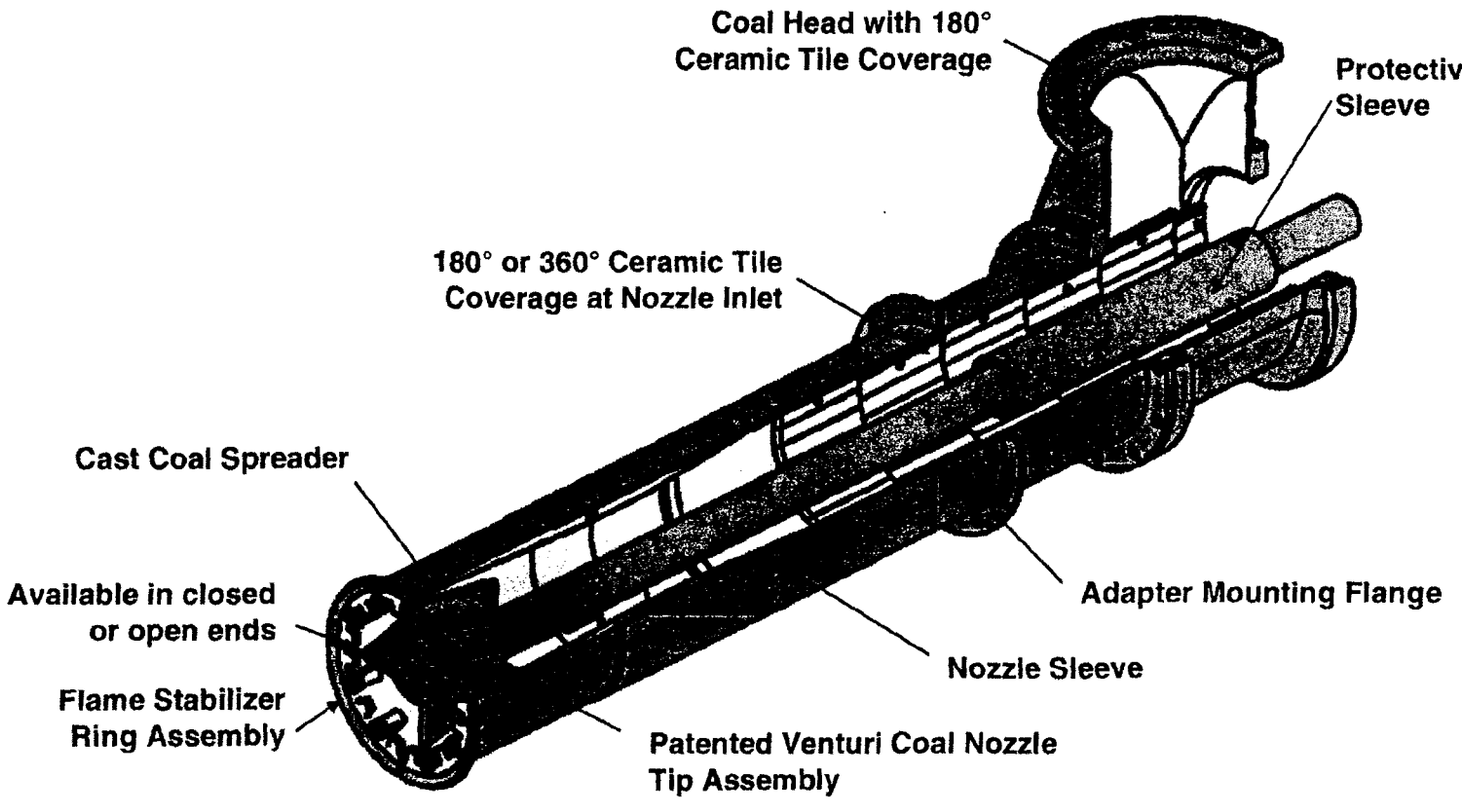


CCV® Single Register Burner

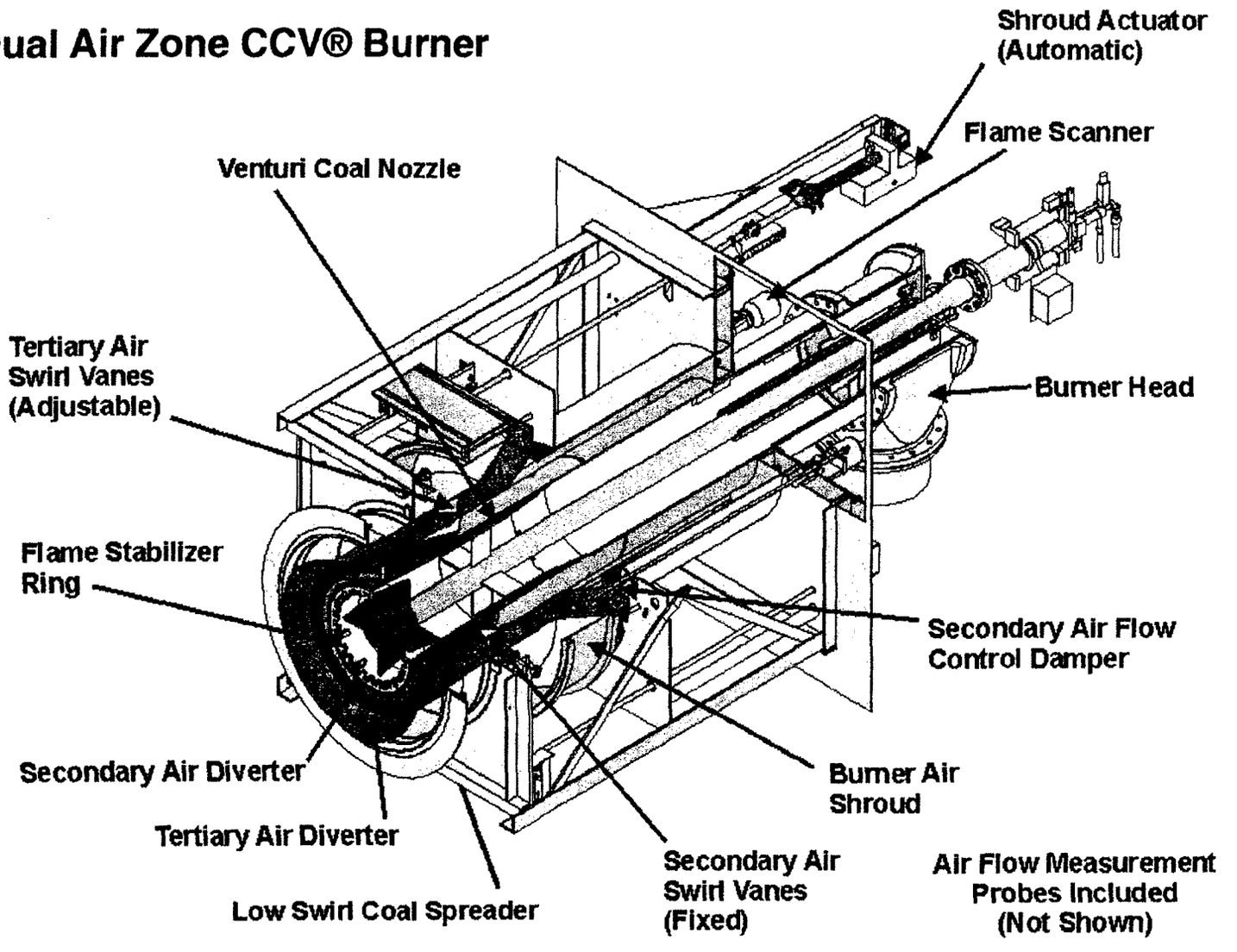


CCV® Dual Air Zone Burner

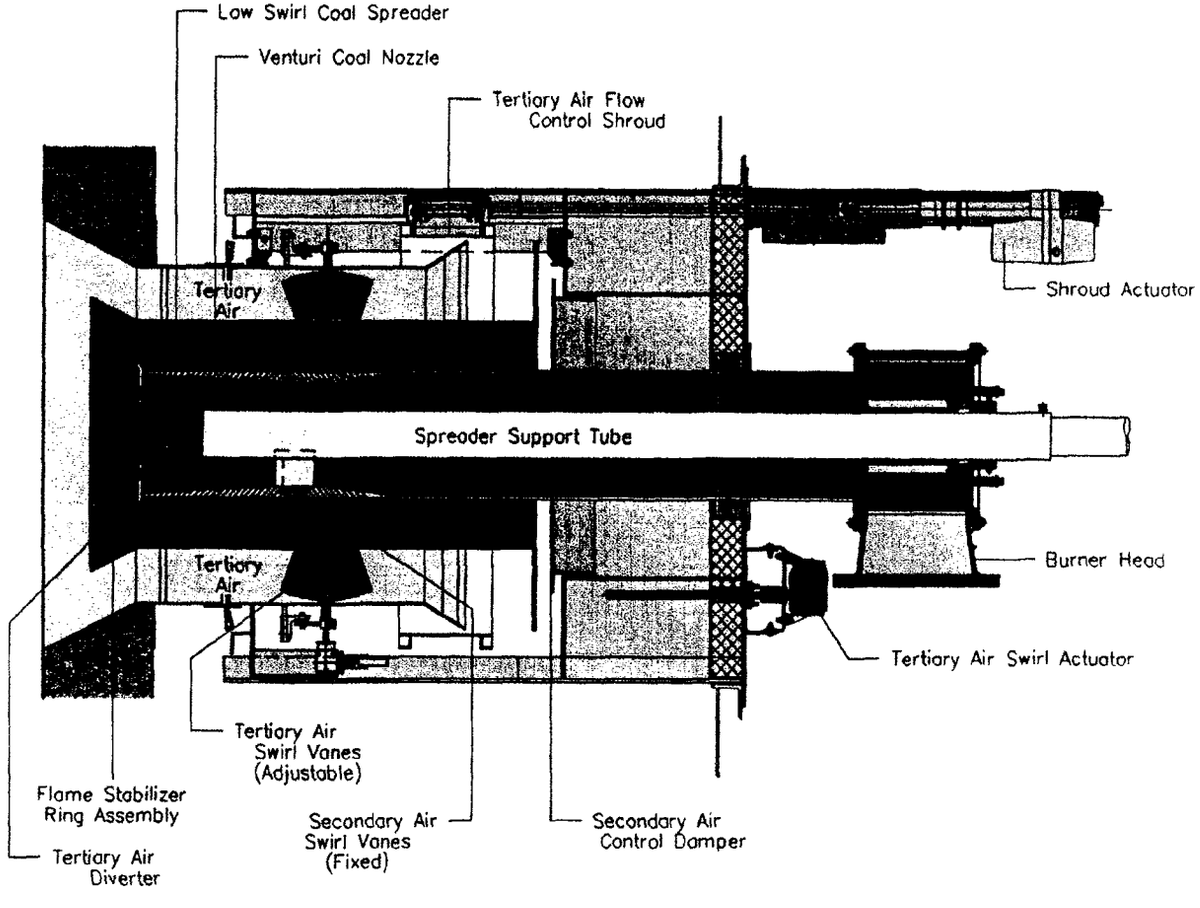
Controlled Combustion Venturi (CCV®) Burner Coal Nozzle



Dual Air Zone CCV® Burner



Controlled Combustion Venturi (CCV®) Dual Air Zone Burner



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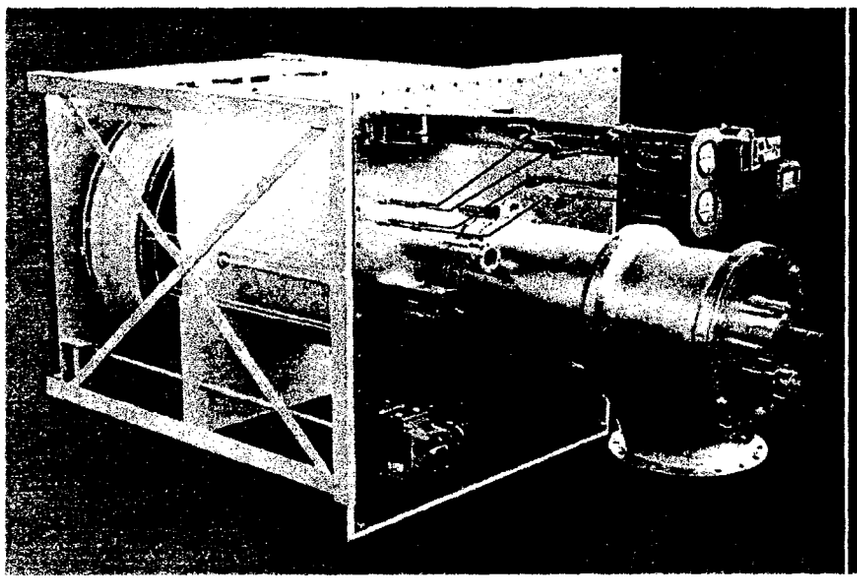
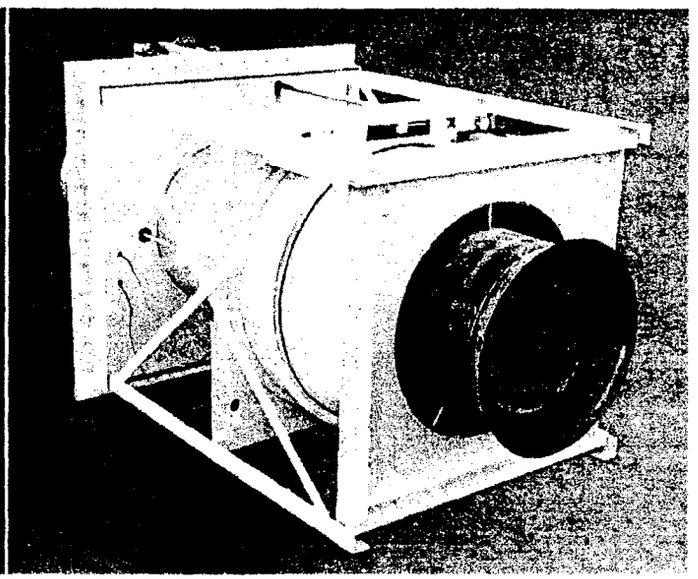
CCV® Dual Air Zone Burner





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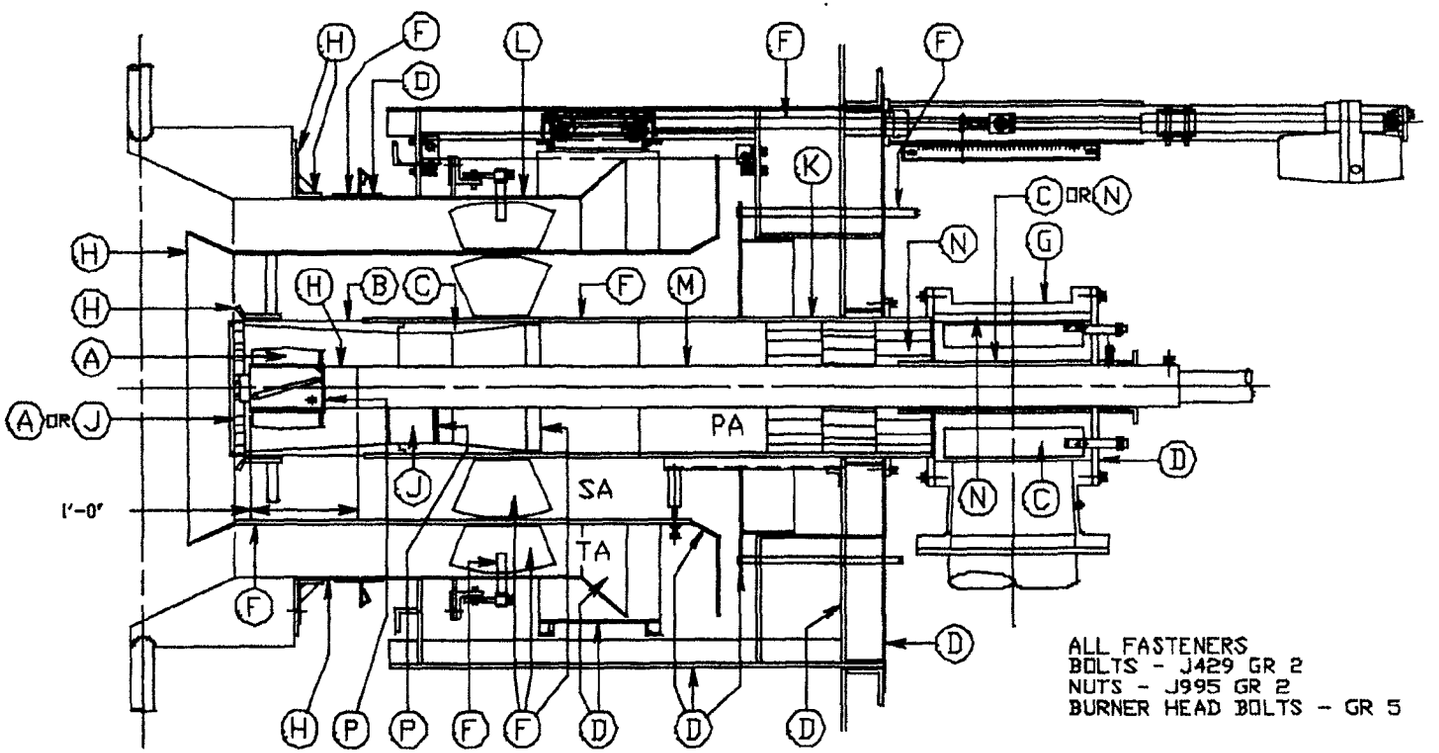


(A) RILOY 74 (50Cr-50Ni-Cb)
(B) 310 SST (CAST)
(C) RILOY 32 or 37 (NI-HARD 1)
(D) CARBON STEEL
(F) 304 SST
(G) CAST STEEL
(H) 310 SST
(J) RA253MA
(K) A36, A106 OR A53 TP E or S GR A or B
(L) A242 TP1 (CORTEN)
(M) A106 B
(N) CERAMIC LINERS (OPTIONAL)
(P) STELLITE #6, Leading Edge (OPTIONAL)

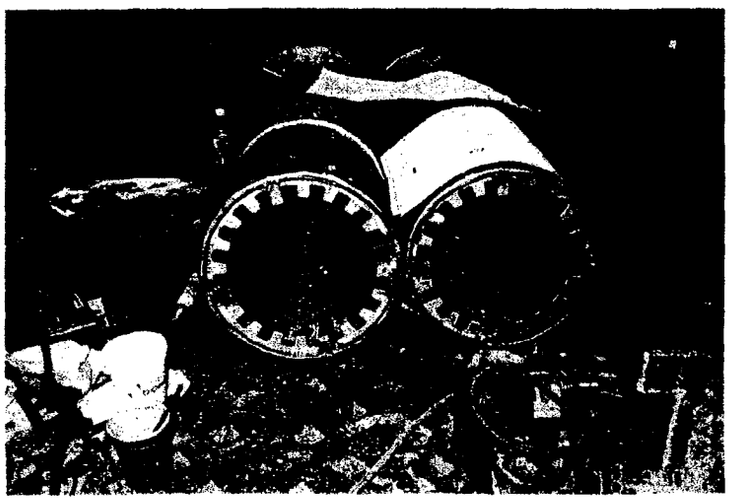
CCV® DUAL AIR ZONE BURNER MATERIALS

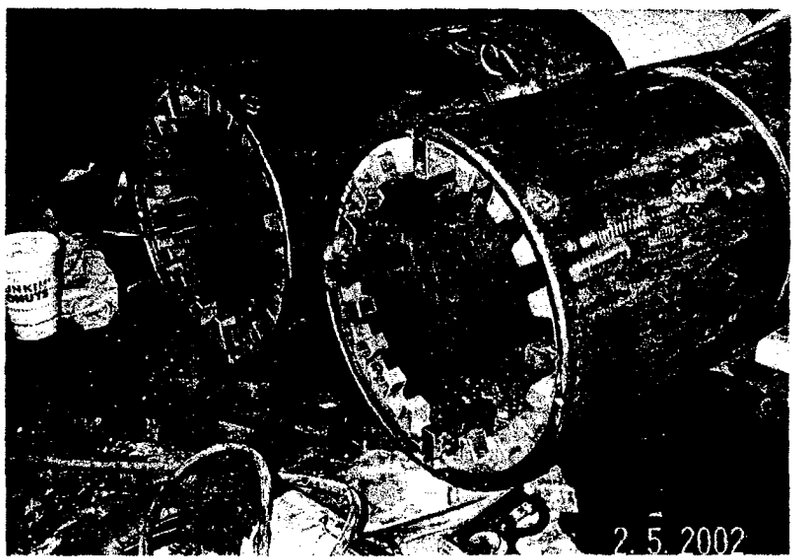
BABCOCK BORSIG POWER

WALL FIRED UNITS WITH WINDBOX DEPTH GREATER THAN 5'-0"

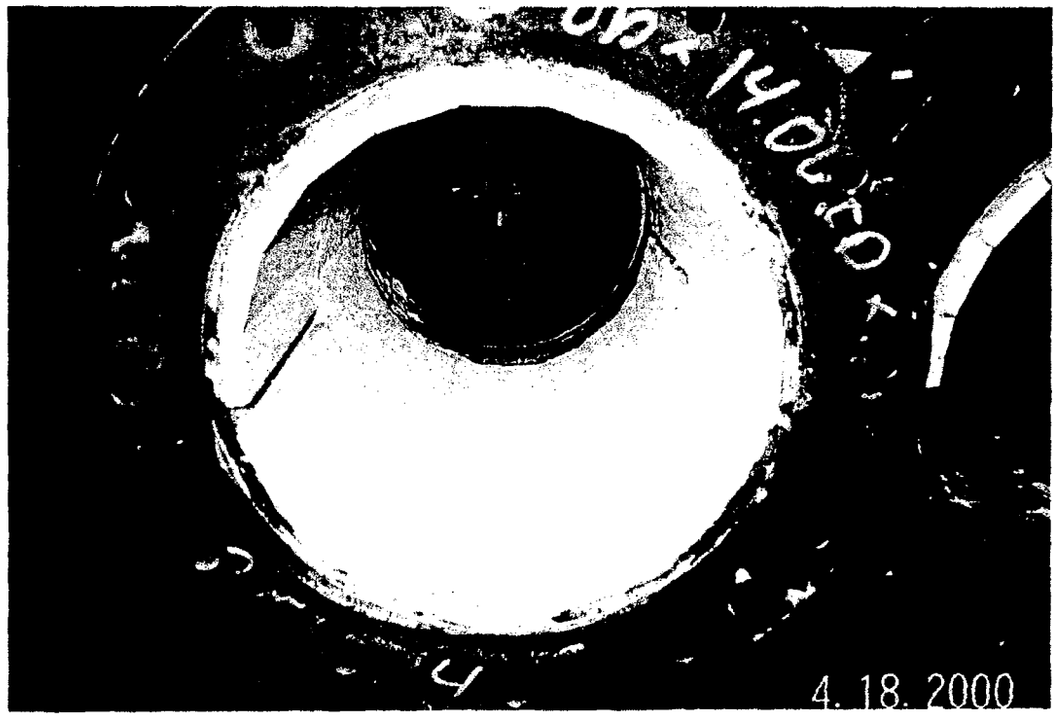
Cad M2128H
Rev. 10-30-01

CCV® Venturi Coal Nozzle

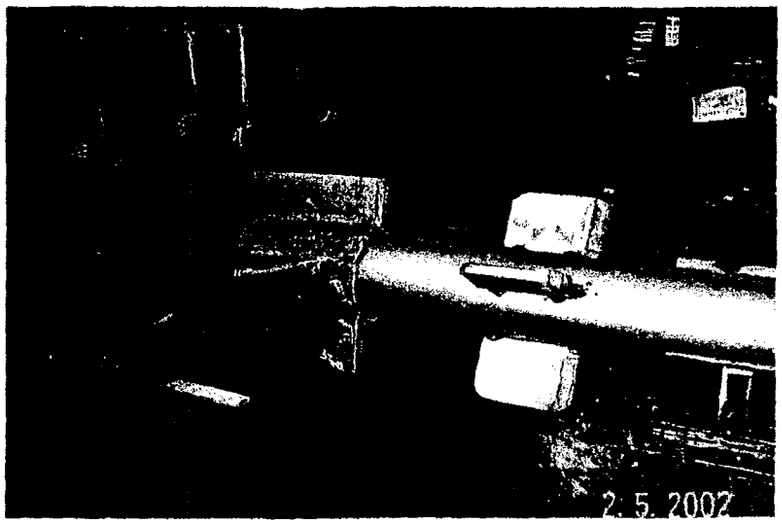




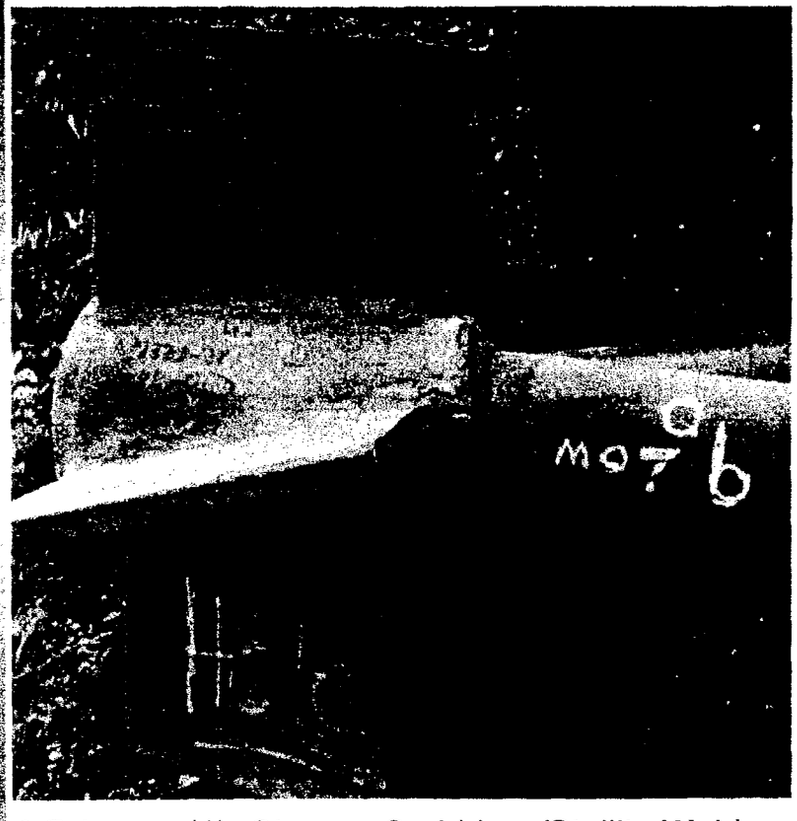
CCV® Burner Ceramic Liners (Heads and Nozzles)



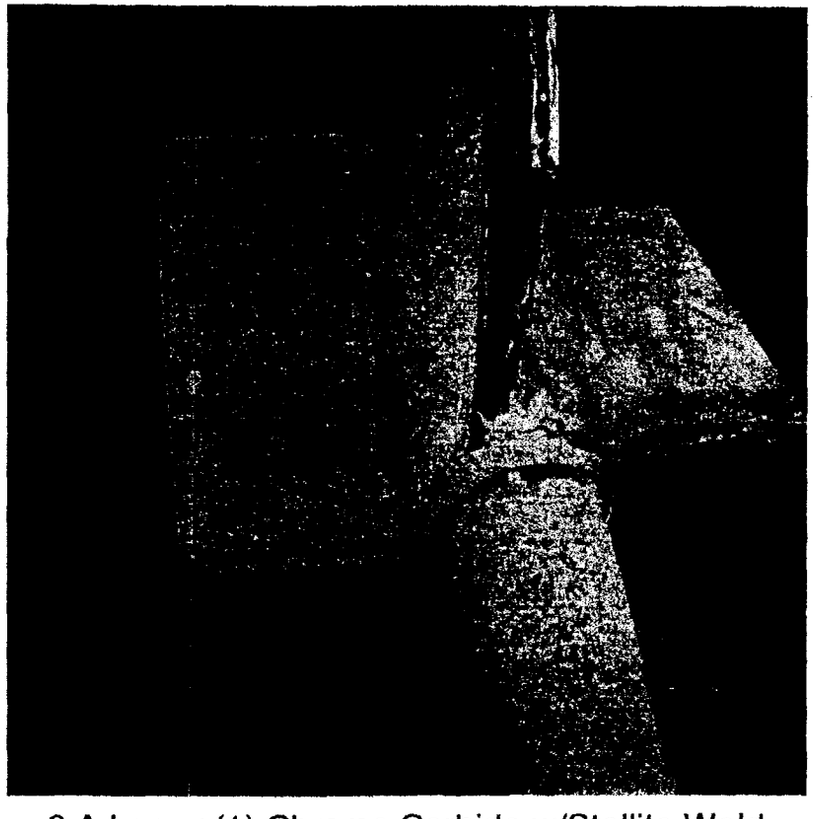
CCV® Burner Coal Spreaders



40,750 Tons of coal per burner in 15 months of operation

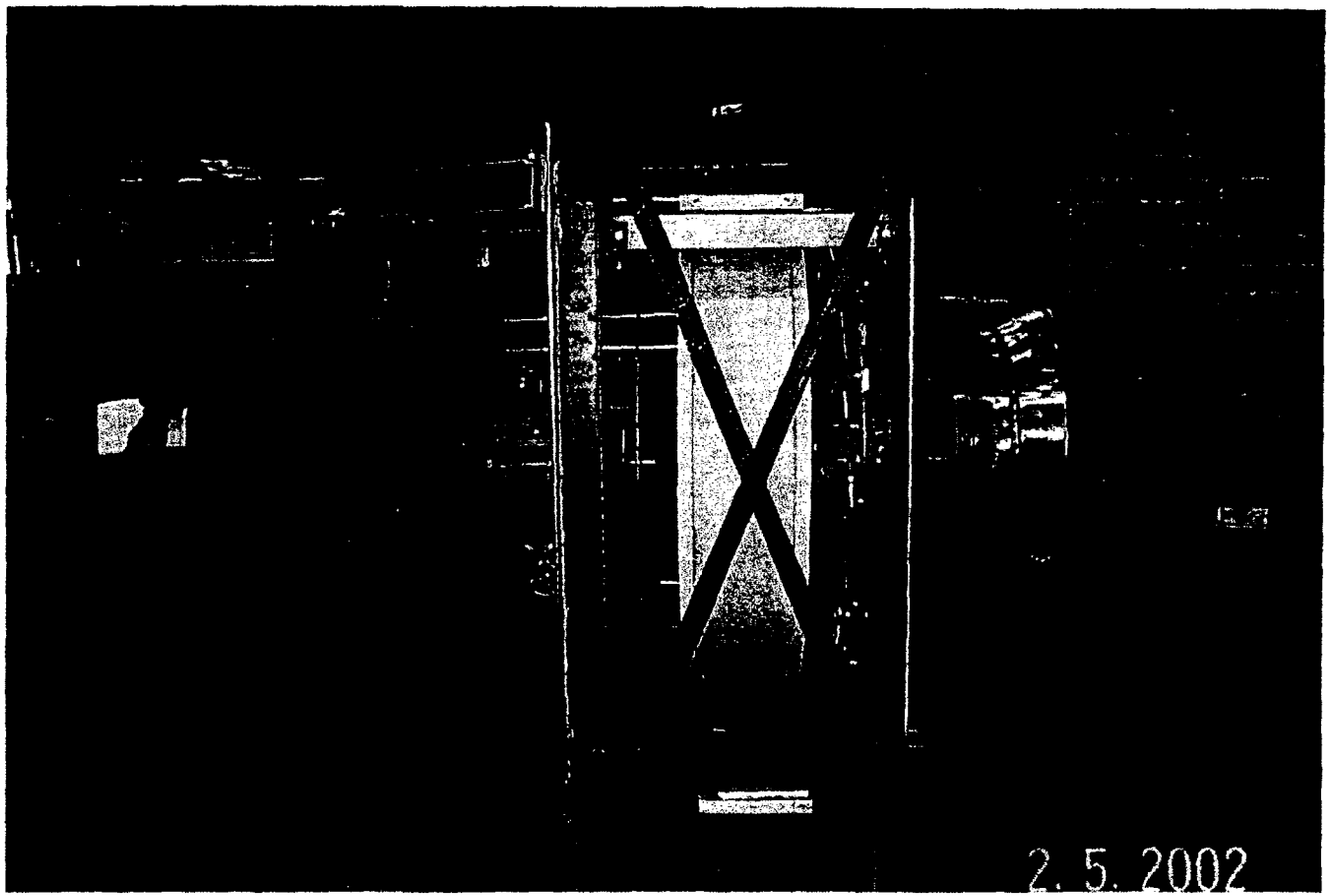


9 D Lower (1) Chrome Carbide w/Stellite Weld

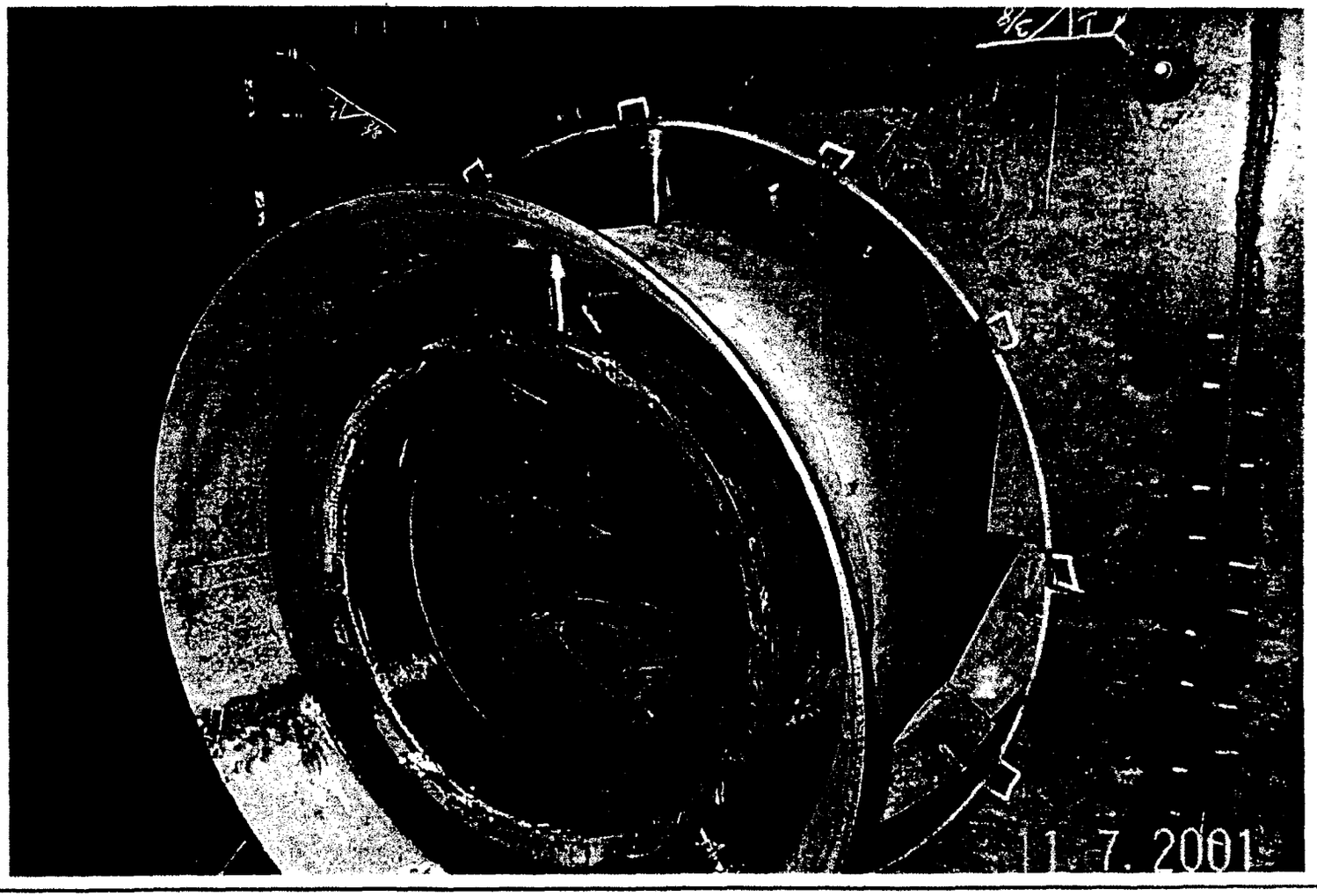


9 A Lower (1) Chrome Carbide w/Stellite Weld

CCV® DAZ Air Register Module



Belle River SA and TA swirl vanes



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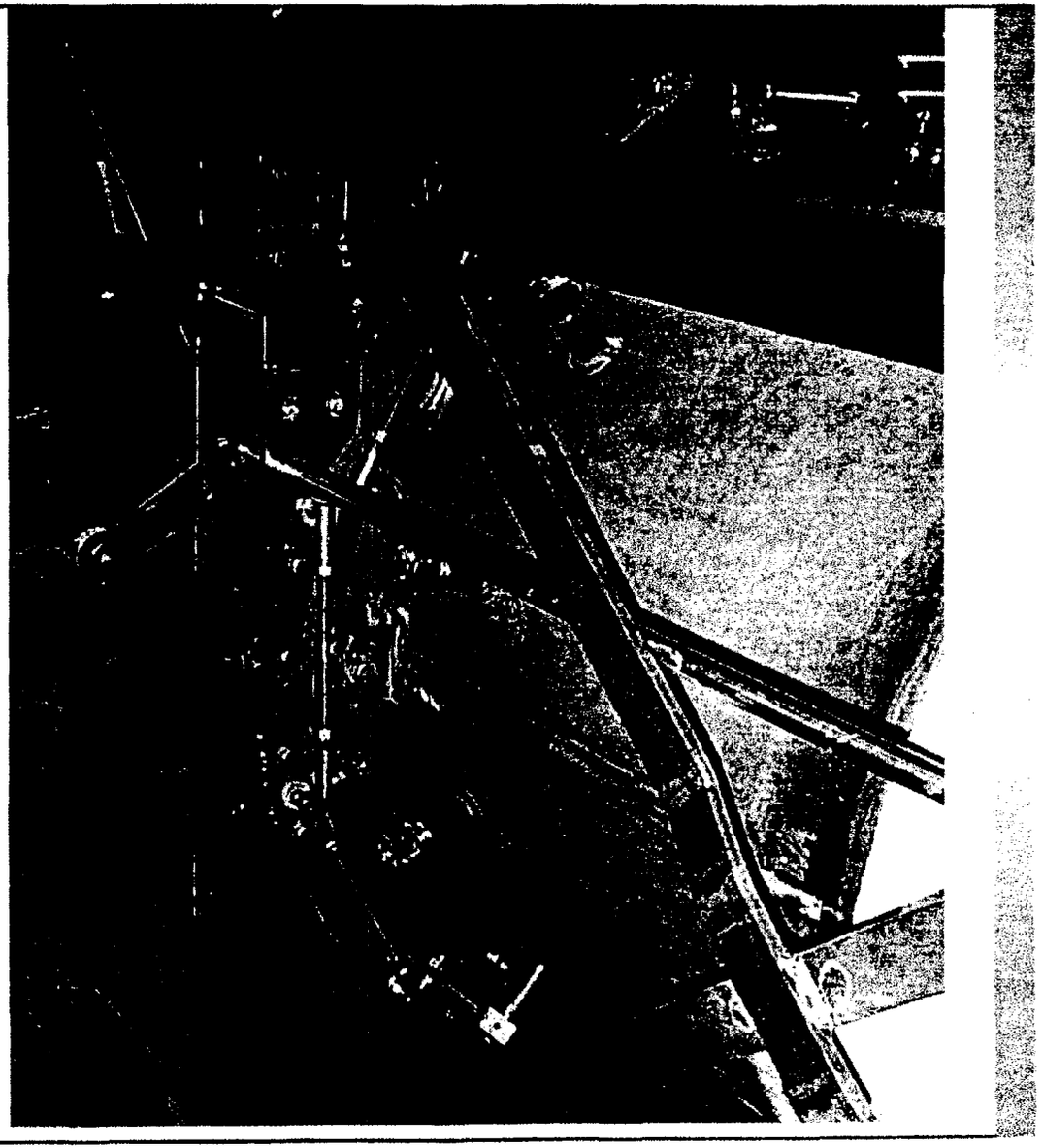
Belle River TA Swirl Vane Control



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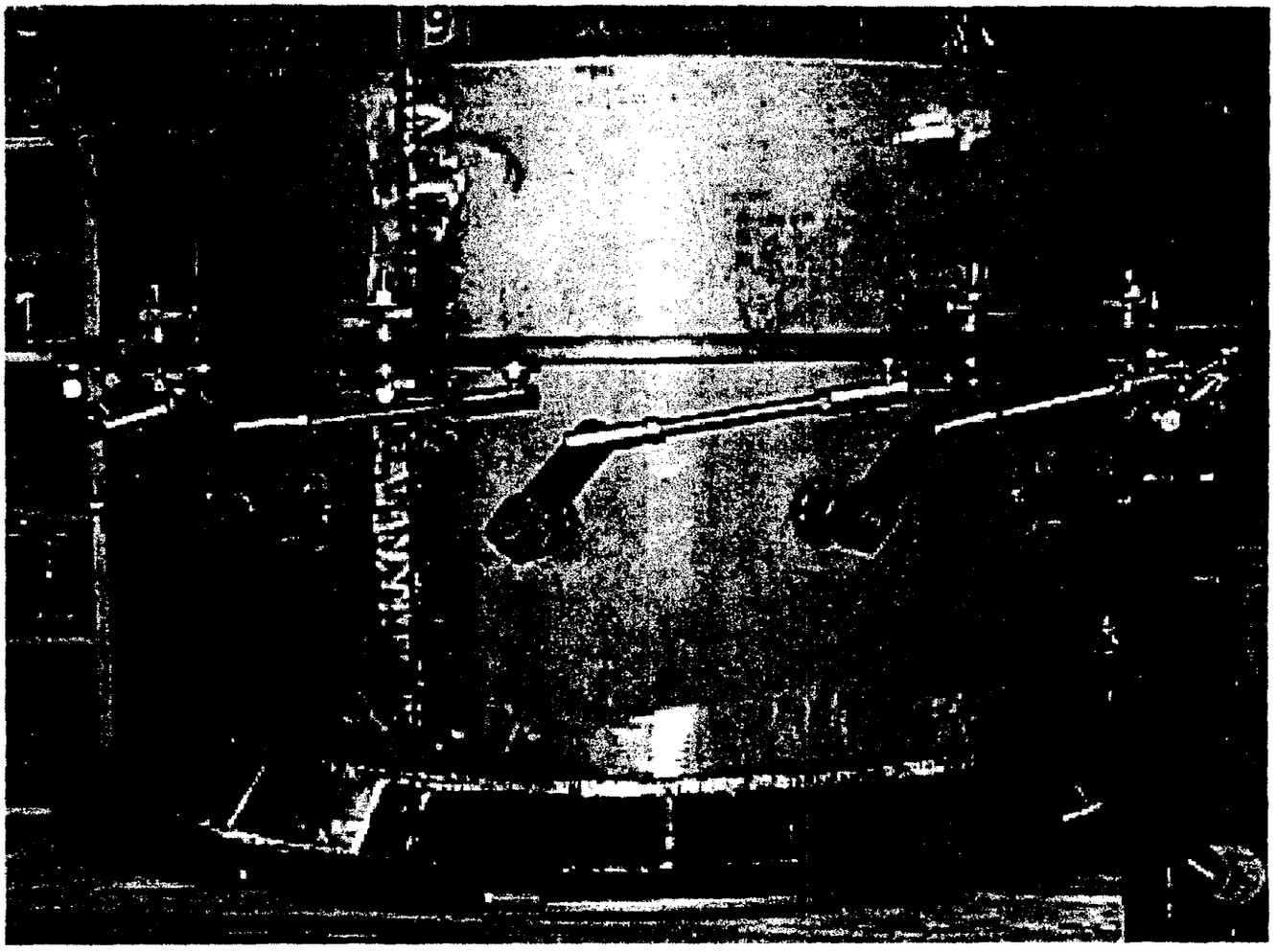
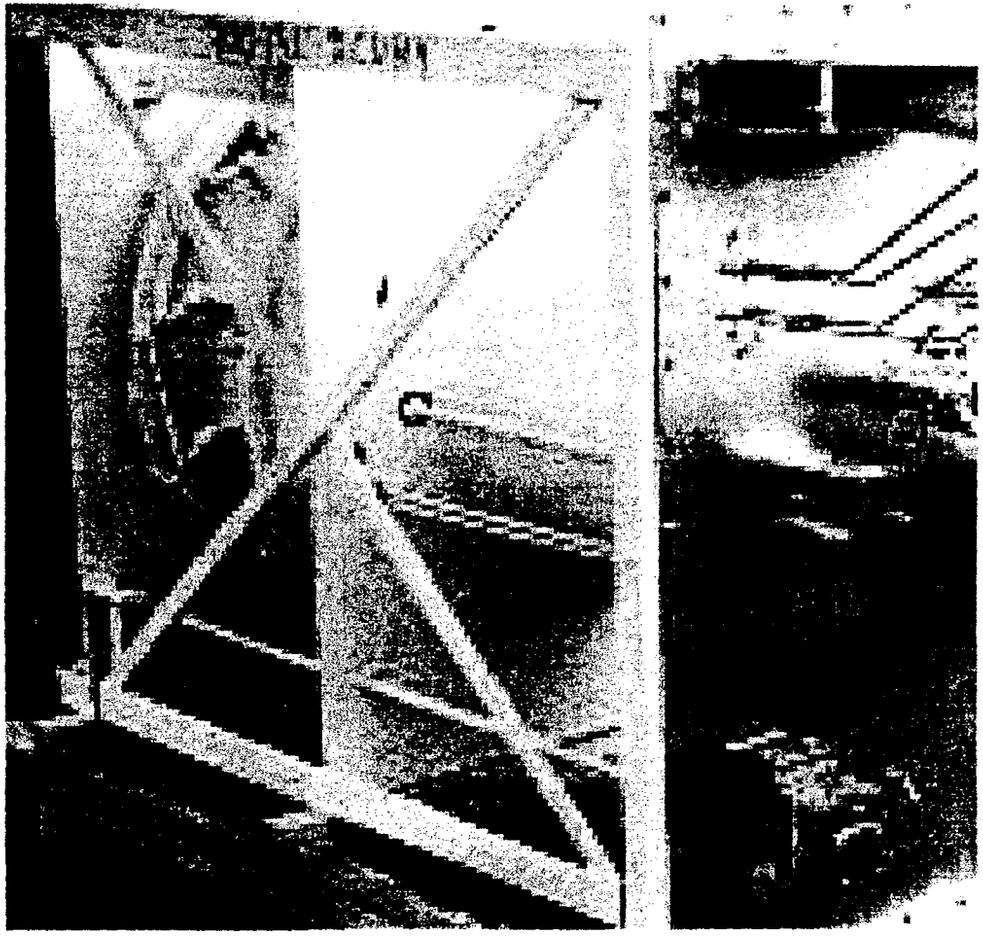
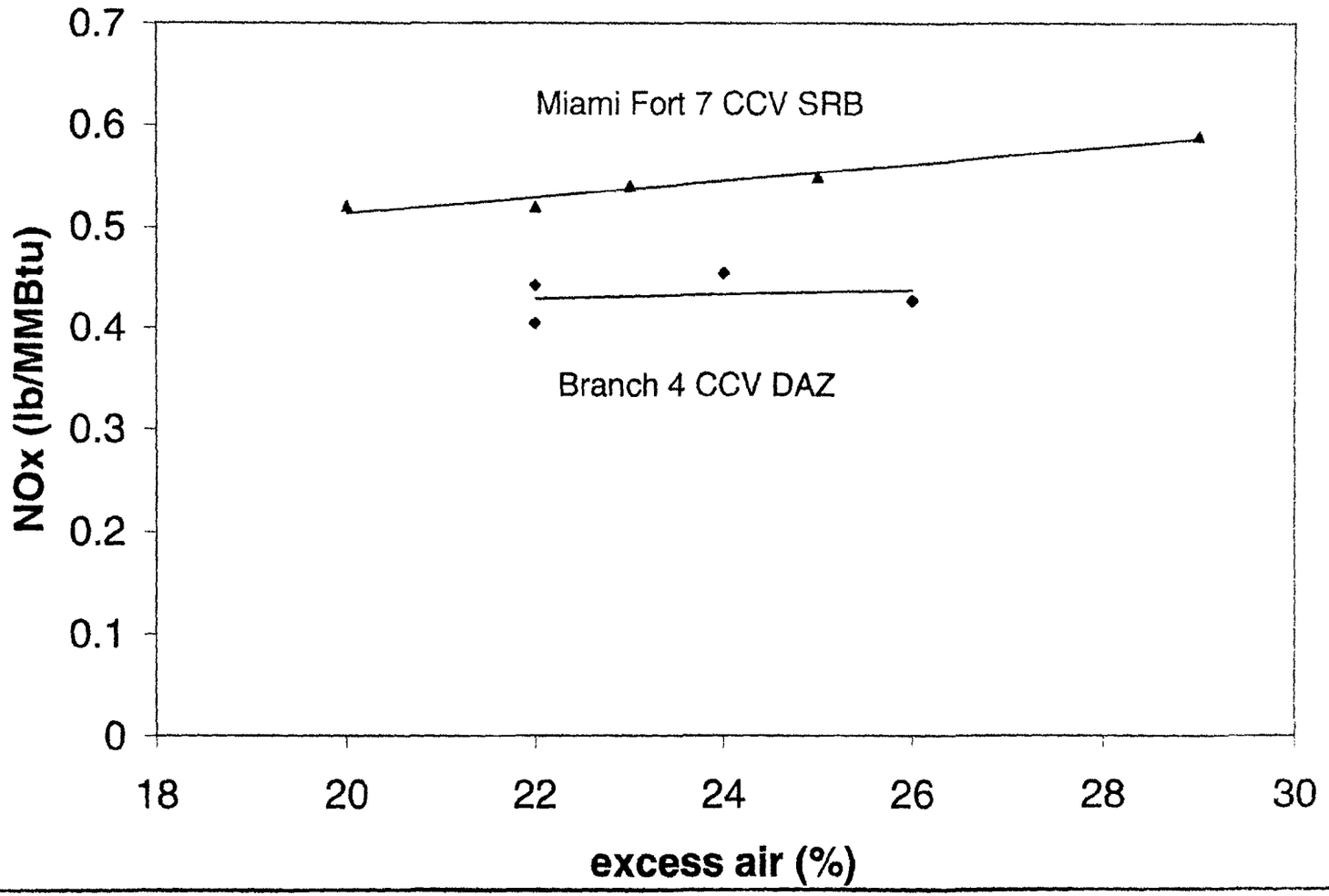
We Energies Presque Isle 6 - TA Swirl Vane Control



Belle River TA Swirl Vane Control



Effect of Excess Air on NOx by Burner Type



Predicted vs. Guaranteed Performance

	prediction	guarantee
NOx (lb/MMBtu)		
CCV DAZ burners only	0.33	0.37
CCV DAZ + OFA	0.30	0.33
CO (ppm)	90	100
flyash UBC (%)		
CCV DAZ burners only	2.8	3.3
CCV DAZ + OFA	< 3.8	4.25

Boiler Test Plan for Over Fire Air System and SH Platen Extension

4/24/03 r3

IGS Unit 1 POST-Outage Testing

Testing Objectives- There are a series of Boiler Tests which are being requested following the modifications which have been made to the Unit 1 boiler. The Unit 1 Major Outage(4 week) modifications consisted of installing an overfire air system and extending the superheater platen section. The objective of the POST-outage testing is as follows:

1) **State of Utah- Required Testing-** document operating conditions after the Overfire Air System has been installed. POST-outage testing is being conducted on the request from the Utah Division of Air Quality based on concerns with an increase in CO emission levels, operating with the overfire air system. The Boiler Testing will be at PRE-Outage test conditions (conducted on 2/25-27/2003) at a Load of 875 MWgross, no Westridge coal, O2% and Overfire Air% varies (see Boiler Test Conditions and Operational Test Setup).

2) **OFA Diagnostics, Tuning and Balancing Testing (to determine best spot to operate and develop control curves).** This test series will help determine the operational curves for the Overfire Air System. Operational parameters that will vary include Load at 950 MWgross, no Westridge coal, O2% and Overfire Air% varies, 1/3 and 2/3 dampers vary to get targeted OFA flow, OFA inlet dampers varied to get balanced flows (see Boiler Test Conditions and Operational Test Setup).

3) **OFA Diagnostics Testing w/ Westridge Blends (to determine best spot to operate and develop control curves)** This test series (which is a continuation of the previous weeks testing) also helps determine the operational curves for the Overfire Air System. Operational parameters that will vary include Westridge coal blend of 25% and 50% and pulverizer configuration, as well as O2% and Overfire Air%, 1/3 and 2/3 dampers, plus inlet dampers (see Boiler Test Conditions and Operational Test Setup).

4) **OFA & SH PLATEN EXTENSION ACCEPTANCE TESTING.** This is the acceptance testing for the Overfire Air and the Superheat Platen Extension. Target acceptance criteria include typical coal mix (25% Westridge Blend), O2% 2.5, OFA% 10 to 15, NOx levels less than 0.37 #/mbtu, and CO less than 100 ppm. (see Boiler Test Conditions and Operational Test Setup).

Test Personal: The testing is being conducted by IPSC Engineering who is leasing test quality gas analyzers from Power Generation Technologies (PGT).

Test Coordinators- Garry Christensen and Aaron Nissen
OFA System Controls and Dampers- Ken Neilson & Phil Hailes
Gas Analyzers and Test Grid- Garry Christensen & Rob Jeffery
Coal & Fly Ash sample collection- Dave Spence & Bill Tanner
Fly ash sample collection- - ISG Rod Hansen, Rick Fowles/ Kurt Aldredge
Babcock Power- Dan Coat1s

Test Method- Testing will utilize the PI data acquisition system to document test conditions. In addition, a test grid is setup at the boiler outlet (11th floor) using 14 test probes at four different depths for a total of 56 points. The gas sampling system is setup with both east and west side averaging systems consisting of bubblers, vacuum pumps, chillers and desiccant filters. The cooled, dry, filtered gas samples are then analyzed for O2, CO2, CO and NOx. Thermocouples are also at each location to get averaged boiler gas outlet temperatures.

NOTE, we will utilize the O2 measurement at the boiler outlet. We are seeing a bias between station O2 and the O2 at the boiler outlet grid. The O2% at the boiler outlet, however, agrees with higher Air Flow shown in CCS, correlates with the higher ID Fan rpm and amps, plus correlates with higher NOx and low CO levels. As part of the testing, we will try to reconcile why we have high station O2 levels.

In addition to east and west side averaged gas conditions, individual test points will also be taken during a separate test to develop backpass test grid profiles. These profiles will include O2, CO, NOx and temperatures which will be used to troubleshoot and diagnosis burner setup and secondary air plus overfire air flow balancing.

OFA System 1/3 and 2/3 dampers plus OFA secondary air inlet dampers will need to be positioned during the course of the testing. One of the 2/3 dampers does not have a drive (NW), so will need to be positioned manually (Ken Neilson holds an OK To to position this damper)..

Fly ash samples will also be taken and correlated with the test results. We will need 2 Operators to help support fly ash sample collection. ISG will be collecting the fly ash samples at each of the different test points. All fly ash hopper rows need to be available (no maintenance work) and hoppers will need to be pulled down prior to the test (night shift) and between each test point.

Coal samples will also be taken throughout the test period at the coal feeder inlet (test taps installed special for testing). Note: there maybe a certain amount of coal spillage created while collecting these coal samples. Bottom ash samples will also be collected.

Boiler Performance Testing- Each test point needs 2 hours, allowing ½ to 1 hour between test points to lower O2, pull fly ash and sootblow for temperatures.

Prior to each test period (daily), the gas analyzers need to be started, warmed up and calibrated. This process takes 1 to 1 ½ hours to complete. During this time, all tubing, bubblers, chillers, desiccant filters, and dust filters will be checked out.

Operational Test Setup- Boiler OFA & Platen Tests

Load (MWgross) 950 (initial Test Point of 875)
Controls– boiler to local (or manual), Boiler Test Objective is for stable boiler/ throttle pressure and let MWs float.
(throttling control valves okay- this is not a turbine test at valves wide open)
Overfire Air System to manual

Throttle Press & Control Valve Position	as needed for load
Main Steam Temp (F)	1005
Main Steam spray (kpph)	<200
Hot Reheat Temp (F)	1005
Reheat Sprays (kpph)	0
Bias Dampers (%)	may have to take PRH side to manual & set between 30- 45%, to control RH temps

Sootblowing as required to achieve Main Stm, HRH and FEGT temps
No sootblowing (during each test period of 2 hrs), sootblowing is allowed between each test
NOTE: for 950 MWg operation, need to allow SH & RH areas to get dirtier, but blow waterwalls to achieve FEGT (furnace exit gas temp) and EGOT (economizer gas outlet temp)

FEGT target (F)	2200, controlled by waterwall sootblowing
EGOT target (F)	760

O2 levels (measured at boiler outlet with test equipment)
VARIES from 3.5%, 3.0%, 2.5%, & 2.0% (plus 1 pt at 1.5% w/ no OFA) at 2 hour increments
Note: there is a discrepancy between station instrumentation and local test analyzers (local reads are higher by 0.5% to 1.0% O2)

Over Fire Air System local control (NW 2/3 damper- drive missing)

1/3 & 2/3 port dampers, VARIES from	0% OFA (baseline), both closed or inlet dampers closed
	5% (2/3 damper closed, 1/3 damper @25%)
	10%(2/3 damper closed, 1/3 damper @100%)
	15% (2/3 damper open, 1/3 damper closed)
OFA inlet dampers	south (SW & SE) dampers throttled 45% to get balanced N to S flows

NOx level target (#/mbtu)	< 0.37
CO (ppm)	< 100
Primary Air Duct Press ("wc)	45

Pulverizer Configuration- 7 I/S, U1H o/s (Sec air damper – 30%)
Note- Remove all pulverizer biasing (unless absolutely necessary due to unmanageable coal dribble)
NOTE: U1 H pulverizer should be available from Maintenance around 5/1/03

Need all normally running equipment in-service (7 Pulv, all FD, PA & ID fans, etc.). This ensures good uniform air and gas flow distribution.

No Boiler Blowdown during the testing period
No Air Preheat system
Isolate Unit 1 CRH to aux steam supply and route all building heat (if in service) drains to Unit 2.

Coal Supply – No Westridge coal for week 1,
Coal blending with WestRidge of 25% and 50% required during week 2
No Rocks, please

NOTES:

1) Fly Ash Samples- need to be taken during each test period (need support of 2 Operators for fly ash sample collection). Fly Ash Hoppers need to be pulled down prior to the test (night shift) and between each test point. ISG will be collecting the fly ash samples at each test points. All fly ash hopper rows need to be available (no maintenance work)

2) Coal Samples will also be taken at each test point at the coal feeder inlet (new test coal sample collection ports). Note: there may be a certain amount of coal spillage created while collecting these coal samples.

3) Bottom ash samples will also be collected during some of the tests.

4) Do not washdown boiler in the backpass areas, due to test equipment, analyzers and computers.

5) PI system – needs to be up and running, no downtime or backups

6) CEM system – PI interface needs to be working

BOILER TEST CONDITIONS SUMMARY
IGS Unit 1 Boiler Overfire Air System and SH Platen Extension POST- OUTAGE Testing

TEST #	DATE & TIME	LOAD MW	TEST CONDITIONS	OFA%	O2%
WEEK 1					
State of Utah Required Testing (to demostrate no increase in CO due to installation of Overfire Air System)					
Day 1	04/28/2003 Mon 7:00- 19:00	**875**	**No Westridge Coal**	0%	2.5
			Pulv U1 H o/s	10%	2.5
			(@expected operation of OFA s	15%	3.0
OFA Diagnostics Testing (to determine best spot to operate and develop control curves)					
Each test point needs 2 hours, allowing ½ to 1 hour between test points to lower O2, pull fly ash and sootblow for temperatures					
Day 2	04/29/2003 Tues 7:00- 19:00	950	**No Westridge Coal**	0%	3.5, 3.0, 2.5, 2.0, 1.5
			Pulv U1 H o/s		
Day 3	04/30/2003 Wed 7:00- 19:00	950	see- Operation Test Setup	5%	3.5, 3.0, 2.5, 2.0
Day 4	05/01/2003 Thurs 7:00- 19:00	950		10%	3.5, 3.0, 2.5, 2.0
Day 5	05/02/2003 Fri 7:00- 19:00	950		15%	3.5, 3.0, 2.5, 2.0
				15%	3.0 TEST GRID PROFILE

NOTE: U1 Boiler Tube Leak Maint Outage (tentatively scheduled 5/3-4/03)

WEEK 2					
OFA Diagnostics Testing w/ Westridge Blends (to determine best spot to operate and develop control curves)					
Each test point needs 2 hours, allowing ½ to 1 hour between test points to lower O2, pull fly ash and sootblow for temperatures					
Day 6	05/05/2003 Mon 7:00- 19:00	950	**Westridge Coal Blend 25%**	0%	2.5
			Pulv U1 H o/s	10%	3.5, 3.0, 2.5
				15%	3.5, 3.0
Day 7	05/06/2003 Tues 7:00- 19:00	950	**Westridge Coal Blend 25%**	0%	2.5 TEST GRID PROFILE
			Pulv U1 H o/s	15%	3.0 TEST GRID PROFILE
Day 8	05/07/2003 Wed 7:00- 19:00	950	**Westridge Coal Blend 50%**	0%	2.5
			Pulv U1 E or D o/s (upper row)	10%	3.5, 3.0, 2.5
				15%	3.5, 3.0
OFA & PLATEN EXTENSION ACCEPTANCE TESTING					
Day 9	05/08/2003 Thur 7:00- 19:00	950	**Westridge Coal Blend 25%**	10- 15%	2.5
			Pulv U1 E or D o/s (upper row)		
			Pulv U1 B or G o/s (bottom row)		
Day 10	05/09/2003 Fri 7:00- 19:00	950	**Westridge Coal Blend 25%**	10- 15%	2.5 (backup test day)
			Pulv U1 E or D o/s (upper row)		
			Pulv U1 B or G o/s (bottom row)		

NOTE: Although we did not BID these tests, *we did collect operating info with 100% Westridge Coal.*
ENVIRONMENTAL TESTING- H2SO4 Testing (required for Unit 3 Permitting Issues)
Utilize coal samples from "as fired" coal sampler and ISG routine fly ash samples

04/22/2002 Tues 7:30- 19:30	950	**Westridge Coal 100%**	Shakedown Tests	
04/23/2002 Wed 7:30- 19:30	950	**Westridge Coal 100%**	15%	3.0
04/24/2002 Thur 7:00- 19:30	950	**Westridge Coal 100%**	15%	3.0
04/25/2002 Friday	900	**Westridge Coal 50%**	15%	3.0